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(54) METHOD AND MEANS FOR WATERBOTTOM LOGGING

(71) We, SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V., a company organized under the laws of the Netherlands, of 30 Carel van Bylandtlaan, The Hague, the Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a method and means for waterbottom logging to obtain information on the composition and thickness of soil layers in the bottom of a body of water by determining the apparent electrical resistivity of the bottom.

The invention relates in particular to a method of waterbottom logging, wherein a plurality of electrodes in electrical contact with the bottom is passed along the bottom in a predetermined direction and in a substantially straight line. The electrodes are arranged in groups of electrodes at least two of which groups are non-overlapping. In carrying out this method, an elternating electrical current is supplied to a first group of electrodes consisting of a pair of current supply electrodes. Simultaneously therewith, potential differences are being measured between parts of electrodes of the other group or groups that do not overlap the first group, and the relationship between the supplied alternating current and the measured potential differences are recorded for determining apparent electrical resistivities.

The invention also relates to a logging for carrying out the above method and carrying electrodes that are subdivided in a first group of current supply electrodes and a second group of measuring electrodes, said groups being arranged along the length of the cable in non-overlapping positions.

This technique of waterbottom logging has been described by J. Bischoff and J. Sebule in their paper 406 "Geo-electrical resistivity methods for use in marine prospection" presented on the Inter Ocean Symposium held in Düsseldorf (W. Germany) in 1976. A simplified model of the waterbottom is assumed, with three layers that are homogeneous and isotropic relative to their resistivity and having parallel boundaries. For a particular electrode configuration, the apparent resistivities of the waterbottom are then calculated for various thicknesses and compositions of the layers. After the apparent resistivities of the waterbottom have been determined by towing a cable carrying current supply electrodes and measuring electrodes along the bottom, the apparent resistivities are recorded and interpretated by comparing them with the data on the apparent resistivities as calculated for the hypothetical waterbottoms.

It has now been found that optimum results may be obtained by arranging the measuring electrodes of the above-mentioned other group or groups in a manner such that the distances between the electrodes of respective pairs of measuring electrodes increase in a direction away from the first group of electrodes.

Further, the configuration of the above-mentioned other groups may be such that a constant ratio exists between the distance between the electrodes of each pair of electrodes between which the potential differences are being measured and the distance between said pair of electrodes and the first group of electrodes. The apparent resistivities determined from the potential differences thus measured can then be interpreted in a cheap and simple manner by comparing them with the data on the apparent resistivities as calculated for the hypothetical waterbottoms on the basis of an electrode configuration of two measuring electrodes and two current supply electrodes, showing a ratio eual to the above ratio.

The invention will be described by way of example in more detail with reference to the drawing, wherein

Figure 1 shows a side view of a vessel towing a measuring cable for carrying out the present technique;

Figure 2 shows a detail of the cablepart carrying the electrodes;

Figure 3 shows a side view of a single electrode arranged on the cable;

Figure 4 shows a particular configuration of the electrodes on the cable;

Figure 5 shows an alternative of the configuration shown in Figure 4; and

Figure 6 shows a special configuration of the type shown in Figure 4.

The logging cable 1 (see Figure 1) is of a flexible nature and carries electrodes in a configuration as shown in any one of the Figures 2, 4 and 5. As shown in the drawing, the cable 1 is being towed by the vessel 2 along the waterbottom 3 consisting of a sand layer 4 on top of a clay layer 5. The cable 1 carries a plurality of electrodes 6—12 as shown in Figure 2, which electrodes are electrically connected by a plurality of electric leads 13 arranged in the cable 1 and suitable for transmitting electric currents and signals to electrical equipment 14 aboard the vessel 1. Figure 3 shows a side view of the electrode 6. This electrode (as well as the other electrodes) consists of a metal (such as steel) ring through which the cable 1 passes. The electrode is mounted (such as by glueing) on the outer surface of the cable 1 and shoulders 15 and 16 are glued at both sides of the ring and the outer surface of the cable 1, to keep the electrode 6 in place. The electrode is connected by an electrical lead 17 to one or more of the electrical leads 13 that are arranged within the cable 1 in an insulating manner.

The electrical equipment 14 (see Fig. 1) aboard the vessel 2 comprises an oscillator for generating a low frequency signal that after amplification is supplied via two of the leads 13 to the current supply electrodes 6 and 7 of the cable 1. Also, the equipment 14 is electrically connected to those of the leads 13 that lead to the electrodes 8—12. The potential differences between pairs of these electrodes are amplified, filtered and recorded on a tape and a printer (forming part of the equipment 14), and together with the recordings of the alternating current supplied to the electrodes 6 and 7. Calculating means are also incorporated in the equipment 14 for calculating the apparent electrical resistivities of the soil areas that are covered by the relevant pairs of measuring electrodes on being towed along the waterbottom. These resistivities are recorded as a function of the areas.

As shown in Figure 2 of the drawing, the distances a-1, a-2, a-3, and a-4 between the electrodes of the respective measuring electrode pairs 8 and 9, 9 and 10, 10 and 11, and 11 and 12, respectively, increase in a direction away from the pair of current supply electrodes 6 and 7. This configuration of the measuring electrodes allows the use of a limited number of electrodes without sacrificing the quality of the information on the relatively deep lying layers of the waterbottom.

A particularly attractive configuration of the electrodes on the cable is shown in Figure 4 of the drawing. The group of current supply electrodes in this configuration consists of two electrodes 20, 21 that are located at a distance b from each other on the cable 22. The group of measuring electrodes consists of the electrodes 23, 24, 25 26 and 27 and is located at a distance c from the group of current supply electrodes. Further, the distances between the pairs of measuring electrodes 23, 24; 24, 25; 25, 26; and 26, 27 are Rc, Rd, Re and Rf, respectively, wherein R is a factor that is larger than 1, equal to 1, or smaller than 1 (but not zero). As is clear from Figure 4, the distances d, e and f are related to one another and to the distance c as follows:

$$
\begin{aligned}
d &= c\ (1 + R)\\
e &= d\ (1 + R)\\
f &= e\ (1 + R)
\end{aligned}
$$

Thus, each pair of measuring electrodes (such as the pair 25, 26) has a distance (Re) between the electrodes (25, 26) that is R-times the distance (e) between said pair of electrodes (25, 26) and the pair of current supply electrodes 20, 21. The application of such a fixed ratio R in the electrode configuration greatly simplifies the number of calculations that are to be made to form graphs that are representative for the apparent electrical resistivities of hypothetical waterbottoms comprising layers of different composition and of a wide scale of thicknesses. Such graphs can now be calculated for any pair of measuring electrodes that is located on the cable the electrodes of said pair having a distance from each other that is R-times the distance between the pair of current supply electrodes and the said pair of measuring electrodes. The graphs thus calculated can now be used for comparison with the measuring results obtained by any of the pairs of measuring electrodes, which clearly allows a considerable simplification of the waterbottom logging technique.

Figure 5 of the drawings shows a configuration of electrodes of the type described hereinabove with reference to Figure 4, but now having a ratio R equal to 1. The distance between the two electrodes 30, 31 belonging to the group of current supply electrodes is g, whereas the distance between the group of current supply electrodes and the group of measuring electrodes 32—36 is h. Further, the distances between the pairs of measuring electrodes 32, 33; 33, 34; 34, 35; and 35, 36 are equal to h, 2h, 4h and 8h respectively. Thus, the distance between the

electrodes of any pair of measuring electrodes is equal to the distances between said pair of measuring electrodes and the group of current supply electrodes.

Figure 6 finally shows an embodiment of the invention comprising three groups of electrodes having a configuration pattern equal to the configuration pattern shown in Figure 5.

The first group of electrodes carried by the cable 39, shown in Figure 6 consists of two current supply electrodes 40, 41 that are located on the cable 39 at a distance k from one another.

The second group of electrodes consists of the measuring electrodes 42—45. The electrodes of the pairs 42, 43; 43, 44; and 44, 45 of this group are situated at distances m, 2m and 4m respectively. The distance between this second group and the first group is m, which is equal to the distance between the electrodes 42, 43 of this second group.

The third group of electrodes consists of the measuring electrodes 46, 47 and 48, and the distance between the electrodes of the pairs of electrodes 46, 47; and 47, 48 is n and 2n, respectively. The distance between this third group and the first group is n, which is equal to the distance between the electrodes 46, 47 of this third group.

In carrying out measurements with the cable shown in Figure 6, an alternating current is supplied to the current supply electrodes of the first group (in the manner as described hereinbefore with reference to the embodiment shown in Figure 2 of the drawing). Simultaneously therewith, the cable 39 is being towed according to a predetermined desired passage along the waterbottom, and the potential differences detected by the pairs of electrodes 42, 43; 43, 44; 44, 45; 46, 47; and 47, 48 and resulting from the alternating current supplied to the waterbottom, are passed on through the (not shown) electrical leads of the cable 39 to the towing vessel. The measured potentials are recorded together with the alternating current and the apparent electrical resistivity of the waterbottom parts below each pair of measuring electrodes is calculated. Comparison of the calculated values with graphs of hypothetical waterbottoms of layers of different composition and various thicknesses allows the operator to map the layers of the waterbottom that is being surveyed. The apparent electrical resistivities of the hypothetical waterbottom have been calculated beforehand on the base of an arrangement of a pair of measuring electrodes that has the electrodes thereof located at a distance from one another that is equal to the distance between this pair of electrodes and the pair of current supply electrodes. Since each pair of measuring electrodes of the cable shown in Figure 6 is arranged in the same manner as the pair of measuring electrodes applied in calculating the graphs representative of the hypothetical waterbottom, it will be appreciated that the configuration of the electrodes shown in Figure 6 allows the use of a restricted number of electrodes on a restricted length of cable, however, without restricting the operator in determining with great accuracy the composition and thickness of the relatively deeplying layers of the waterbottom.

Each group of measuring electrodes should consist of at least two pairs of electrodes. Two of these electrodes may be located at the same point and be replaced by a single electrode. Each group of measuring electrodes then consists of three electrodes. Application of the invention is, however, not limited to this particular number of three measuring electrodes that are carried by a common cable. More than three electrodes may be used as well. Also, the invention is not limited to a particular number of groups of measuring electrodes that are being applied on a common cable.

Although the current supply electrodes shown in the embodiments of the invention are all in a leading position with respect to the groups of measuring electrodes when the cable is being towed along the waterbottom, the invention is by no means restricted to such a configuration of the electrodes with respect to the towing direction, since the same measuring results will be obtained when the cables shown in the drawing are being towed along the water in a substantially straight line in opposite direction.

Although application of the electrode shown in Figure 3 is preferred for carrying out the present method, electrodes of other construction may be applied as well. On being towed along the waterbottom, the electrodes should preferably contact the bottom or be within the mud layer generally present on such waterbottom.

WHAT WE CLAIM IS:—

1. Method for waterbottom logging to obtain information on the composition and thickness of soil layers in the bottom of a body of water by determining the apparent electrical resistivity of the bottom, wherein a plurality of electrodes in electrical contact with the bottom is passed along the bottom in a predetermined direction and in a substantially straight line, the electrodes being arranged in groups of electrodes at least two of which groups are non-overlapping, supplying an alternating electrical current to a first said group of electrodes consisting of a pair of current supply electrodes, measuring potential differences between pairs of electrodes of the other group or groups that do not overlap the first group, and recording the relationship between the supplied alter-

nating current and the measured potential differences for determining apparent electrical resistivity, wherein the distances between the electrodes of respective pairs of measuring electrodes of the other group or groups increase in a direction away from the first group of electrodes.

2. Method according to claim 1, wherein the electrodes are being passed along the waterbottom in a configuration wherein a constant ratio exists between the distance between the electrodes of each pair of electrodes between which potential differences are being measured and the distance between said pair of electrodes and the first group of electrodes.

3. Method according to claim 2, wherein the ratio is equal to 1.

4. Method according to claim 2 or claim 3, wherein there are at least two groups of electrodes at which potential differences are measured, said groups overlapping each other in the pre-determined direction.

5. Method according to any one of the claims 1—4, wherein each other group consists of at least three measuring electrodes.

6. Method for waterbottom logging, substantially as described in the specification with reference to Figures 1, 2 and 3, Figure 4, Figure 5 and Figure 6 of the drawing.

7. Logging cable for waterbottom logging comprising a flexible cable with insulated electrical leads, and carrying electrodes on the outer wall thereof each electrode being electrically connected to one or more of the leads, said electrodes being arranged along the cable in a configuration consisting of groups of electrodes at least two of which groups are non-overlapping, a first group of these electrodes being current supply electrodes, and the electrodes of the other group or groups that do not overlay the first group being measuring electrodes for measuring potential differences between at least two pairs of electrodes of the or a respective group, the distance between the electrodes of these latter pairs increasing in a direction away from the first group of electrodes.

8. Logging cable according to claim 7 wherein there exists a fixed ratio between the distance between the electrodes of each pair of measuring electrodes and the distance between said pair of measuring electrodes and the first group of electrodes.

9. Logging cable according to claim 8, wherein said ratio is equal to 1.

10. Logging cable according to any of the claims 7—9, carrying at least two groups of measuring electrodes that overlap one another along the cable.

11. Logging cable according to any one of the claims 7—10, wherein the electrodes comprise metal rings through which the cable passes.

12. Logging cable according to any one of the claims 7—11, wherein each other group of electrodes comprises at least three electrodes.

13. Logging cable for waterbottom logging substantially as described in the specification with reference to Figure 2, Figure 4, Figure 5 and Figure 6 of the drawing.

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1588495 COMPLETE SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale

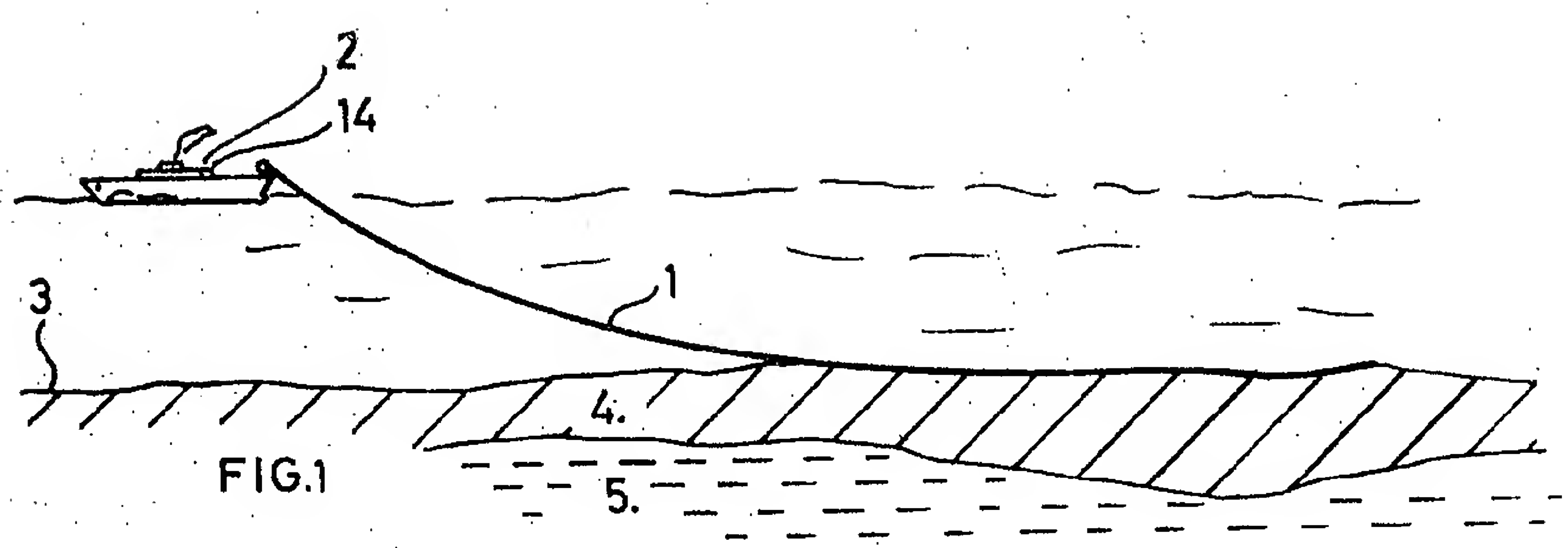

FIG.1

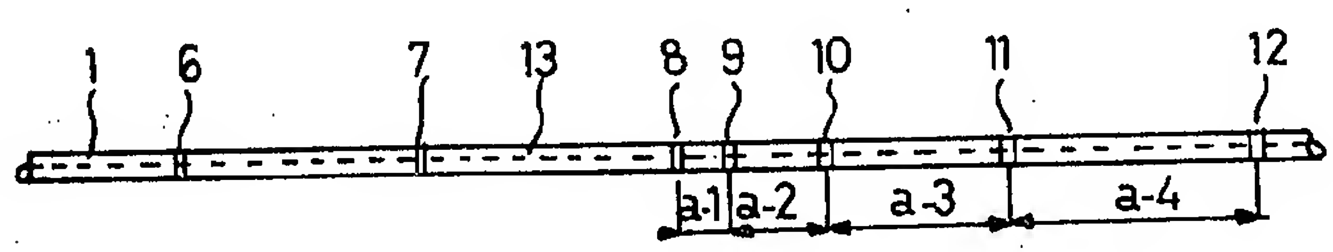

FIG.2

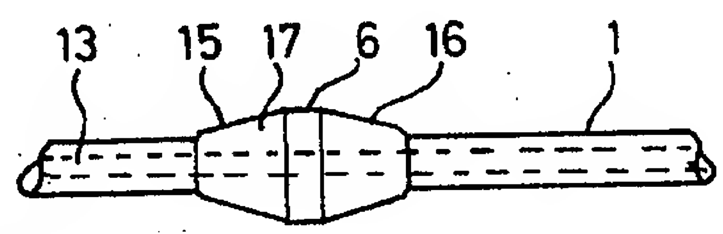

FIG.3

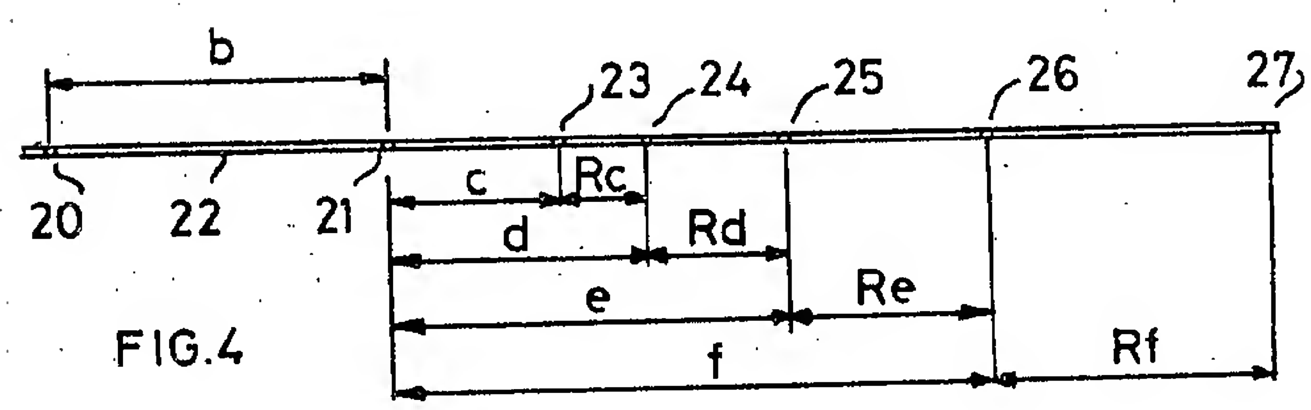

FIG.4

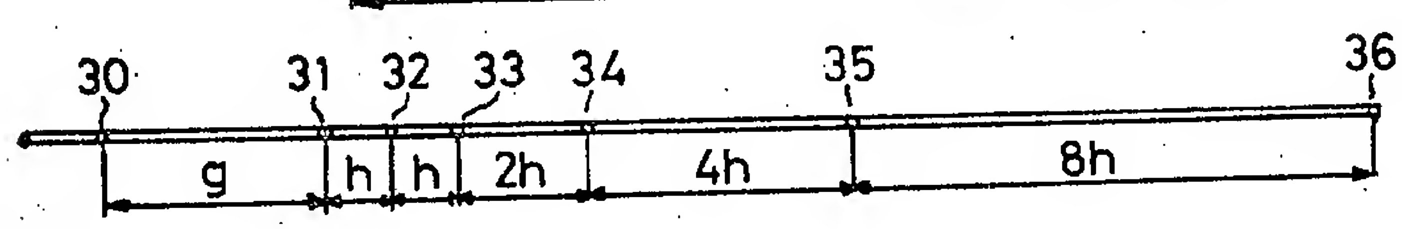

FIG.5

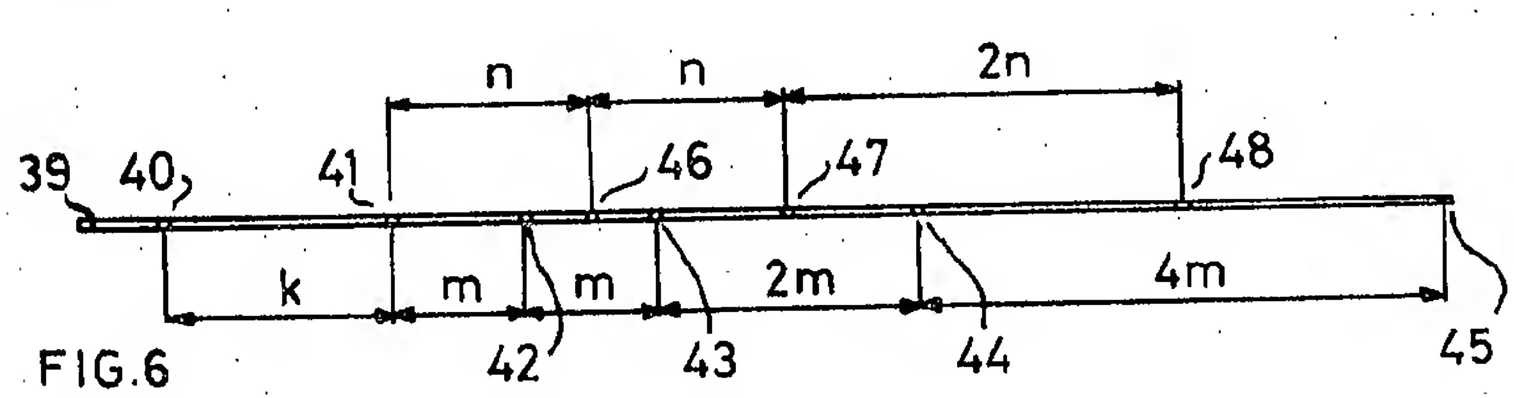

FIG.6